

OPTICAL AND MICROWAVE DETECTION USING Bi-Sr-Ca-Cu-O THIN FILMS

B.E. Grabow, Department of Electrical and Computer Engineering, Johns Hopkins University, 3400 N. Charles St, Baltimore, 21218, MD

R.M. Sova, and B.G. Boone, Electro-Optical Systems Group, Johns Hopkins University Applied Physics Laboratory, Johns Hopkins Rd., Laurel, MD, 20707

K. Moorjani, B.F. Kim, J. Bohandy, F. Adrian, and W.J. Green, Microphysics Group, Johns Hopkins University Applied Physics Laboratory, Johns Hopkins Rd., Laurel, MD, 20707

Recent progress at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) in the development of optical and microwave detectors using high temperature superconducting thin films will be described. Several objectives of this work have been accomplished, including: deposition of Bi-Sr-Ca-Cu-O thin films by laser ablation processing (LAP), development of thin film patterning techniques, including in-situ masking, wet chemical etching and laser patterning, measurements of bolometric and non-bolometric signatures in patterned Bi-Sr-Ca-Cu-O films using optical and microwave sources, respectively, analysis and design of an optimized bolometer through computer simulation, and investigation of its use in a Fourier transform spectrometer. This paper will focus primarily on results from the measurement of the bolometric and non-bolometric response.

Typical samples are deposited on single crystal MgO substrates at 300 °C in the LAP cell. They are shadow-masked during deposition and annealed after deposition at 880 °C for 10 minutes, preceded and followed by a 75 minute ramp-up and a 3 hour ramp-down relative to room temperature. Silver epoxy contacts are placed on the sample and annealed-in during film annealing, a procedure that almost always eliminates contact resistance problems. In addition, we find that the samples can be thermally recycled many times with little degradation of the contacts or the intrinsic film properties, and they can be reused after a long shelf-life.

For optical detection, a 4 mW helium-neon (HeNe) laser (633 nm wavelength) beam was chopped at 26 Hz and focused onto the center of the sample. For microwave detection, a 9 GHz microwave signal was generated with a microwave oscillator and square wave modulated at 40 Hz with a PIN diode modulator. The signal was then amplified and fed into an X-band horn positioned directly in front of the sample. In both cases the induced output voltage from the sample was synchronously detected with a lockin amplifier.

Results for the optical detection experiment indicate a response peak located at the center of the transition region. From standard bolometric theory, it is known that the bolometric response is proportional to the derivative of the resistance curve. Calculated derivatives of the resistance curves correlate well with the measurements. Thus we believe that the optical response is primarily bolometric. In addition, measurements of the lockin response versus chopper frequency indicate a response time consistent with a thermal response mechanism.

The measured voltage response for various microwave power levels indicates that the peak of the response varies linearly with microwave power until saturation is reached. Unlike the optical response, the peak in the microwave response is located (in temperature) in the region of the resistive tail well-below T_c and clearly separated from the optical bolometric response peak. This implies that the microwave response is non-bolometric. As expected, the width of the resistive tail increases with increasing microwave power. More interestingly, several characteristics of the microwave response change as a function of increasing bias current; not only does the response height increase, but both its position decreases (with temperature) and its width increases as current increases. In addition, lockin response to microwaves does not rolloff with chopper frequency as does the optical response, implying the response mechanism is not thermal.

Noise voltage measurements were also taken with an equivalent noise bandwidth of 1 Hz. Even with no illumination the sample has a response in the resistive tail region. In addition, peak excursions of the noise voltage in the region of the peak were much higher than the RMS noise voltage levels. This behavior would be expected if individual transient fluctuations occur in the film over very short time intervals, perhaps associated with flux motion and dissipation. With increasing bias current, the characteristics of the noise peak resembled the behavior of the microwave response peaks. We also determined that there is a decrease in the noise level versus temperature just above the non-bolometric peak, which probably corresponds to a drop in thermal noise associated with the resistive transition.

Several hypotheses could be put forward to explain the microwave response peak, and they are currently under study. A detailed theoretical and experimental study of the microwave response, however, is required to resolve the question of the non-bolometric mechanism and is currently underway. Some of the efforts and their results will be described. Eventually we hope to exploit this phenomenon as a faster, more sensitive technique for microwave detection than the bolometric optical response.